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CR-128744

Contract NAS 9-12646

FACTORS CONCERNED WITH SANITARY LANDFILL SITE SELECTION: GENERAL DISCUSSION

Written by

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August 31, 1972

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Prepared for the National Aeronautics and Space Administration as part of contract NAS-9-12646 by members of the Civil Engineering Department, University of Houston, Houston, Texas, 77004.

FOREWORD

This is the first of several technical reports to be issued describing specific tasks undertaken as part of the research effort of Contract NAS-9-12646 entitled "Application of Remote Sensing." Two additional reports are in preparation at the time of issuance of this first report.

The second report in the series, to be dated September 30, 1972, will discuss the regulatory restrictions governing the location of sanitary landfill sites and the physical characteristics of the 18 county region around Houston known as the Houston Area Test Site (HATS).

The third report, to be dated October 31, 1972, will discuss the social and economic aspects of site selection, and the implications regarding other selection criteria and operational techniques.

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August 31, 1972

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I. INTRODUCTION

Today the influence of solid waste disposal on the environment is a matter of increasing concern to everyone. In the United States in 1970, approximately 200 million tons of solid waste were collected from all non-industrial sources. By 1980, this should increase to an amount between 235 million and 260 million tons (1). Most of this huge amount of waste materials ultimately will end up in sanitary landfills. There are three methods commonly used for solid waste disposal: incineration, sanitary landfilling, and composting. Among these, sanitary landfilling is considered at present the most practical and economical method, and is therefore widely adopted. The use of incineration, composting, or new and innovative recycling methods may be increased in the future. In the opinion of the writers, however, sanitary landfilling will continue to be necessary. Landfilling is the only final disposal technique. Environmentally and economically speaking, sanitary landfilling can be the most successful waste disposal method provided proper planning, engineering and operation are utilized. Because of some of the pollutional aspects of landfills and the fact that an increasing number of landfills will be required, it is important that the most suitable locations be selected in the most efficient manner possible.

With this objective in mind, the following report has been prepared. It is the first of several interim reports regarding site selection for sanitary landfills. This report presents a general discussion of the factors affecting site selection, while subsequent

technical reports will give more specific details applicable to the particular area being studied.

This general discussion is the result of extensive literature review, site visitation, group analysis, and the authors' experience. The discussion is oriented toward practicality in site selection. The conclusions drawn are the result of many considerations and hopefully point toward better site selection practices. Certainly the importance of site selection criteria is emphasized. In later reports specific methods or procedures useful in making site evaluations will be presented.

II. TYPES OF SOLID WASTES AND SANITARY LANDFILLS

A. Definition of a Sanitary Landfill

A sanitary landfill is defined by the American Society of Civil Engineers as: "A method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation, or at such more frequent intervals as may be necessary (2)."

A sanitary landfill should be designed as a system, with prime consideration given to materials to be deposited, site selection, construction and operational techniques, and utilization of the completed fill, all of which weigh heavily on the degree of protection afforded to the ground water of the area. The term "waste" means unwanted or discarded materials resulting from commercial, industrial and agricultural operations and normal community activities. Wastes include solids, liquids and gases. Wastes which are solid or semi-solid containing insufficient liquid to be free-flowing are classed as solid waste.

Such a landfill is a well-controlled and environmentally safe method of disposal of solid wastes. Four basic operations are performed (3). These operations are: 1) the solid wastes are deposited in a controlled manner in a prepared portion of the site; 2) the solid wastes are spread and compacted in thin layers; 3) the

solid wastes are covered daily or more frequently, if necessary, with a layer of earth; and 4) the cover material is compacted daily.

Oftentimes in present day circumstances landfilling disposal operations are considered inadequate or poor. Inadequate disposal practices are primarily the result of lack of planning and financing. It is seemingly true that in the past cities have devoted too little effort to locating and reserving future lands for sanitary landfill sites as part of their planning for community growth. Thus it becomes increasingly more difficult, especially in large urban areas, to locate suitable disposal sites.

B. Classification of Solid Wastes and Sanitary Landfills

Most of the states in the United States classify their waste materials into the following categories: municipal, commercial, industrial, institutional, and special or hazardous. In general, these may be described as follows:

(1) Municipal and Commercial Waste:

Solid waste resulting from or incidental to municipal, community, trade, business and recreational activities including wet garbage, rubbish, ashes, street cleanings, bottles, boxes, paper, cans, wooden boxes, plastics, yard trimmings, miscellaneous trash and all other solid wastes except industrial.

(2) Industrial Waste:

Solid waste resulting from or incidental to any process of industry, manufacturing, mining or agricultural operations

including discarded and unwanted solid materials suspended or transported in liquid and discarded; or unwanted materials in liquid or semi-liquid form.

(3) Institutional Waste:

Solid wastes from schools, rest homes, and hospitals are usually highly compactible and can be handled in the same manner as municipal and commercial wastes and are often delivered along with them. Pathological wastes are usually disposed of in a special type of incinerator.

(4) Special or Hazardous Wastes:

Acids and other chemicals, dead animals, animal waste, abandoned vehicles, sewage treatment residue, and construction and demolition waste such as waste building materials and rubble from construction, remodeling, repair, and demolition of houses, commercial buildings, pavements and other structures.

As a guide to prescribing requirements for disposal at solid waste disposal sites, such wastes can be subdivided into three groups:

Group I. Toxic and hazardous chemicals (wastes with significant water pollution potential), e.g., liquid and/or soluble wastes, and toxic industrial ashes and chemicals.

Group II. Ordinary household municipal and commercial refuse such as rubbish, garbage, other decomposable organic refuse, and scrap metal of the nature to be indicated at safe elevations above anticipated high ground water elevation

in the vicinity of the site, e.g., empty tin cans, metal containers, metal scraps, paper and paper products, cloth and clothing, wood and wood products, etc.

Group III. Non-water soluble, nondecomposable inert solids of the following nature, e.g., earth, rock, gravel, asphalt paving fragments, glass, plaster and plaster board, steel mill slag, clay and clay products, manufactured rubber products, etc.

Corresponding to the grouping of solid wastes, sanitary landfill sites can be classified into three types. These are:

Type 1 -- located on land over non-water bearing sediments or on marshy land with only unusable groundwater underlying the surface.

Type 2 -- located within a canyon, gravel, or borrow pit, and in open areas underlain by usable confined groundwater.

Type 3 -- located in an area that affords little or no protection to receiving waters.

A Type 1 site can accept refuse from waste Groups 1, 2, or 3. Materials suitable for disposal in a Type 2 site are Group 2 and 3 wastes. Materials suitable for disposal in a Type 3 site are only Group 3 wastes.

With respect to pollution of surface and ground water, the most important factors governing landfill site selection and classification are the physical characteristics of the environment surrounding the

site. These characteristics, namely, geology, hydrology, and topography, determine the degree of protection which a particular site affords. This in turn determines the type of refuse which can be deposited.

C. Sanitary Landfill Operational Methods

Three general methods of landfilling have developed: the area method, the trench method, and the slope or ramp method (3). A description of each method and the sites best suited for each are given.

1. Area

In the area landfill method the solid wastes are placed on the land surface. A machine, often a bulldozer, spreads and compacts the wastes and then covers the wastes with a layer of earth. This layer is then compacted. The method is best suited for marshes, flat areas, or gently sloping land. It is also used in quarries, ravines, valleys or where suitable land depressions exist. The earth cover is usually hauled in or obtained from adjacent areas.

2. Trench

In the trench landfill method a trench is cut in the ground and the solid wastes are placed in the trench. The wastes are then spread, compacted, and covered with the earth excavated from the trench. This method is best suited for

flat or gently sloping land where the water table is not near the surface. The major advantage of the method, sometimes called the cut-and-cover method, is that cover material is readily available with a minimum of hauling or moving.

3. Slope or Ramp

The slope or ramp method is actually a combination of the area and trench methods. In this method the solid wastes are dumped on the side of an existing slope. The wastes are then spread, compacted and covered with earth obtained just ahead of the working face. The cover material is then compacted. This method is generally suited to all areas which are not flat.

With this introduction to sanitary landfills, it is believed that the reader should now gain a more complete understanding of the following discussion regarding the effects of site selection on the overall acceptance and satisfaction of a sanitary landfill. Until recently the general trend in site location for sanitary landfills has been to place a landfill almost anywhere and let the operational and maintenance procedures make the site successful. To some extent this practice is still followed. The connotation of successful here means that a certain land area has been used to dispose of solid waste, that the land value has not been depreciated by this use, and that environmental pollution has been avoided. The words "environmental pollution" are used to denote both aesthetic values and actual pollution to the air, water or land.

III. FACTORS PERTAINING TO SITE SELECTION

General factors pertaining to site selection may be divided into the following classifications: physical, social-political, economic and regulatory. Any one of these considerations can deter site location from a specific land area. Often priority given to one classification can lead to poor site selection. The most abused of these considerations are probably the physical factors. As mentioned, dependence is oftentimes placed on operational and maintenance procedures to make a site successful. This may be possible; however, one need only to visit a landfill operation to observe that proper operational procedures are things to be written about but in actuality frequently do not occur. This is one reason that site selection procedures should be developed for optimum location of landfills with respect to the physical characteristics of the site and the surrounding area. In other words, it would seem advisable that priority should be given to the physical considerations over other considerations. It appears that oftentimes in the past social-political considerations have been the initial and determining factors in site selection when actually they should be incorporated last after potential sites have been selected.

A. Physical Characteristics

Physical characteristics may be described under four main topics: topography, hydrology, climatology and geology (4). These are natural characteristics and should be distinguished from land use

characteristics which are often considered in physical analysis. Land use will be discussed in the sections dealing with social-political and economic considerations.

In considering a large land mass, such as the United States, it has been found that the importance of a particular physical characteristic of the land varies from one region to another. Therefore, in this general report, the physical characteristics are presented without regard for the importance of each characteristic in determining the acceptibility of a site. In a subsequent report, a specific priority system will be presented. This priority system, which will be applicable to the Houston Area Test Site*, will serve to point out that any priority system regarding evaluation of landfill sites must be regional in nature.

1. Topography

Judging from an extensive literature review, it has been concluded that practically any type of topography can be used for a sanitary landfill, especially so if present practices are the measure. It should be noted, however, that some land forms will require extensive site development and expensive operational techniques. The best topography is, in general, flat or gently rolling land not subject to flooding. A landfill should not be located in a flood plain because of the water pollution hazard and

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*NASA designation for an eighteen county region of Texas centered about Houston. The counties are: Austin, Brazoria, Brazos, Burleson, Chambers, Colorado, Fort Bend, Galveston, Grimes, Harris, Liberty, Matagorda, Montgomery, San Jacinto, Walker, Waller, Washington and Wharton.

because such a site can become unusable both during and after a flood. Landfills located in such areas require special engineering design compatible with the site conditions.

Land reclamation is being practiced by the use of solid waste as a fill material. Natural eroded areas, such as canyons and ravines, and man-made pits -- such as strip mines, quarries and gravel pits -- are being used as sanitary landfills in some locales. Gully reclamation has been demonstrated in Sarpy County, Nebraska (5) and at Big Springs, Texas (6). The Sarpy County landfill, completed in August 1968, is being used as farm land for corn production. The Big Spring landfill, completed in October 1970, is being utilized for grazing land. In Frostburg, Maryland (7) a strip mine is being reclaimed. In Norristown, Pennsylvania (6) a quarry is being reclaimed. These examples indicate that in specific locations, land reclamation and solid waste disposal are a workable combination.

Wet areas such as marsh and tidal lands may be filled and reclaimed. At least one landfill in the vicinity of Houston is located in a wet area and site investigation indicated that possible ground and surface water pollution could occur. Furthermore, at the time of the visit no operational procedures were being employed to limit the excessive contact that was occurring between waste materials and the water. Besides the objection to using wet areas for landfills based on possible water pollution, there is objection from an ecological point of view. Marsh lands and swamps have considerable ecological value as nesting and

feeding grounds for wildlife. Objections of this sort are discussed in the section on social-political considerations.

The preceding paragraphs have pointed out the fact that at the present time very little emphasis is being placed on an area's topography in considering that area for a landfill site. One conclusion of this study is that more emphasis should be placed upon an area's topography and less on the dependence upon operational procedures in order that a successful sanitary landfill can be maintained and completed. Consideration of the pollution potential noted at some of the landfills in the Houston area and those reported in the literature was a major factor in reaching this conclusion. Also, topographical study of a possible landfill area will reflect the potential flooding conditions during heavy rains and snow melts. Special attention should be given to sites that might be drainage basins for surrounding areas. Surface water drainage and flooding can quickly erode cover material and the refuse field.

2. Hydrology

In recent years considerable information has been reported pertaining to the hydrological factors associated with sanitary landfills. The potential danger of ground and surface water pollution resulting from a landfill cannot be overlooked. Solid wastes ordinarily contain many contaminants and often infectious materials (4, 8, 9). Serious health hazards or nuisances can result if these pollutants are permitted to enter water supplies.

a. Surface Water

The Solid Waste Management Office, USEPA, has recommended that surface water run-off be diverted from entering the fill (10).

Surface water infiltrates the cover soil and enters the compacted solid wastes. Ordinarily this would not cause a problem in well mixed and well compacted fill where the moisture content ranges from 20 to 30 percent by weight. The presence of excessive water, whether from surface run-off, ground water, or that resulting from decomposition of food wastes and other readily degradable organics, will produce leachate. In general a sizable portion of the fill must become saturated before leachate is produced.

Besides diverting run-off, the effect of surface water can be minimized by grading and sloping the daily and final cover soil to facilitate run-off, and by choosing as cover materials fine grained soils with good workability and relatively low permeability.

b. Ground Water

Ground water connotes the water contained in the soil or rocks below the standing water level. The standing water level is that level at which the ground water finally stands in a hole which is left open for several days. Below this level all the pores of the ground are filled with water, i.e., saturated, while above it capillary attraction of some fine grained soils may cause water to rise above the zone of

saturation. Conditions affecting occurrence and level of ground water are complex and it is advisable to employ the assistance of a qualified ground water hydrologist. The zone of saturation is sometimes discontinuous, both laterally and vertically. The hydrologist can determine this and also predict the direction of flow of ground water and the nature of the aquifer.

A geological investigation of the site should be made to determine the pollution potential of ground and surface waters. Elements of study should include ground water quality, rate and direction of movement, discharge points, the effects on nearby well use, and the depth and variability of ground water. A minimum distance of 2 to 5 feet between the high ground water level and bottom of the fill has been recommended by EPA (10).

c. Leachate

The term leachate is applied to the aqueous solution of the decomposition products formed by water passing slowly over the degradable organics in a landfill. The liquid is high in biological and chemical oxygen demand (BOD and COD) and dissolved chemicals -- such as iron, chloride, and sodium -- and hardness.* Leachate can result from two sources: (1) rain water infiltrating the landfill, taking into solution various chemicals as it passes through the refuse in the fill; (2) it

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*A term used to describe those waters requiring considerable amounts of soap to produce a foam or lather; the condition is caused by calcium and magnesium metallic ions, primarily.

may result from saturation of refuse placed below the water table or due to a rise of water levels in the disposal zone. The leachate becomes part of the natural hydrologic flow system and may discharge as surface runoff or recharge the underlying groundwater. This integral association of the leachate with the hydrologic flow system is the reason that hydrogeologic knowledge and concepts should be applied to the selection of landfill sites to prevent groundwater pollution. Determination of the type, texture, relative permeability, and sequence of geologic deposits and a determination of the groundwater flow-system and seasonal fluctuations, should be required where humid conditions exist. Knowledge of these factors will enable evaluation to be made concerning potential groundwater pollution and the required renovation of leachate whether done naturally or by man induced treatment. Some authorities recommend removing leachate from landfills as surface drainage so that it may be monitored for its pollution potential and treated, if necessary. In a completed landfill the quantity of leachate and the intensity of its contaminating quality decreases with time.

3. Climatology

Climatology should always be considered in site selection. Wind direction, frequency and intensity are important since litter and dust control must be maintained. This is another aspect of site location which is important and yet is often overlooked. Again, operational and maintenance procedures are oftentimes

depended upon for control. Rainfall intensity, duration, and seasonal variation should be considered. Sometimes the use of wet weather landfill areas is made necessary by heavy rainfall in a region or locality.

In the regions of the country where precipitation exceeds evaporation, a net volume of water results to replenish soil moisture and recharge ground water (9). Therefore, leachate production is inevitable from most landfills. Gas is produced by the natural decomposition of organic matter facilitated by inherent moisture and by additional moisture seeping into the material. Leachate and gas production are the two main pollutional aspects of sanitary landfills which can occur even if proper operational procedures are maintained.

In arid areas the importance of leachate is not great. This is due to insufficient precipitation to satisfy the soil moisture deficiency and infiltrate the refuse. Also, the zone of saturation is usually deep enough so that refuse will not be buried below the water table. Consideration of this factor reflects that priorities given different site selection characteristics must be based on regional or a site-to-site basis.

Another climatic factor to consider is temperature. Temperature to a certain extent determines the type of vegetation found in a location. This is important not only from a evapo-transpiration-rate standpoint but also in controlling the rate of runoff. Runoff affects the amount of surface water which will infiltrate the soil. In areas where the temperatures are often below freezing, landfill

cover material may be difficult to obtain due to frost. A well drained soil is more easily worked in freezing weather than a poorly drained soil.

4. Geology

The last classification of physical characteristics to be discussed is geology. This term is used loosely to mean consideration of the top soil and underlying bedrock.

It is essential that the geologic conditions and the nature of the soils around, beneath, and in the proposed site be known. A layer of the proper type of cover material is needed to deter the ingress and egress of rodents, birds, flies, and other insects.

The base of a sanitary landfill should act as a barrier to prevent leachate from entering uncontrolled into the groundwater. Thus two different types of soils are necessary for proper control of sanitary landfill sites.

The U. S. Soil Conservation Service has prepared a rating system of soil limitations for sanitary landfills (11). The following soil properties are evaluated on a slight-moderate-severe limitation scale: depth to seasonal high water table, soil drainage classes, flood hazard, permeability, slope, soil texture, depth to bedrock, stoniness and rockiness.

The primary consideration in evaluating the depth to the seasonal high water table and in determining the soil drainage class is the degree and duration of wet soil conditions that make earth moving operations difficult. This same consideration is the primary factor in evaluating the potential for contamination of

groundwater. The permeability rating applies to the most permeable layer below the A horizon.* Soils with low permeability are most desirable because they minimize the probability of polluting groundwater by either verticl or lateral moisture seepage. Permeable horizons near the bottom of a landfill may be sealed by compacting a blanket of relatively impervious material one to three feet thick along the sides and bottom of the fill.

Some of the considerations pertaining to slope are that more grading is generally required to provide roads to and from landfills located on sloping-to-steep soil than on more level land. Also, more care is needed to provide for the proper disposal of surface water from adjacent areas. In the trench type landfill the bottom should be kept as level as possible because it tends to

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*The A horizon is the soil mechanics designation for the surface soil, i.e., the zone of eluviation where rock debris and soil materials weather and disintegrate in place. It is also the principal zone for leaching. The thickness of this top layer usually ranges from a few inches to about 3 feet. Immediately below this layer is the B horizon, also called the zone of accumulation. This lower horizon usually contains finer-grained material and often is much more surface-chemically active and unstable than the soil either above it or below it. These characteristics make the B horizon extremely important in highway and airfield design and construction or in other work in which the foundations are located near the ground surface. The B horizon is, generally speaking, 2 to 4 feet thick. Below this is the C horizon, a layer ranging from a few inches to over 100 feet in thickness. Material in the C horizon is in the same physical and chemical state as when it was first deposited by water, wind, or ice in the geological cycle. This horizon often furnishes the bulk of the material of which large soil structures, such as earth dams, levees, and embankments, are constructed. The contact between these horizons is not a sharply defined line or plane; the change from one to another occurs through interfacial zones of variable thickness.

act as a seepage plane. The refuse layer offers little impedance to the movement of water and difficult seepage problems could result in the completed landfill.

The rating for soil texture is based on the ease of digging in the trench type fill and on the ease of using the soil material for daily and final cover. Soil texture indicates workability which is important because of the need to move material daily during dry and wet periods and sometimes in freezing temperatures. Soils which are plastic and sticky when wet are difficult to excavate, grade, or compact. Trying to place a layer of wet clayey soil material in uniform thickness over a cell of refuse is difficult.

A soil survey is a valuable tool to use in site selection. It is not a substitute for detailed geologic investigation because SCS soil borings are normally limited to depths of six feet.* Since many landfills use trenches as deep as 15 or more feet, the geological investigation is necessary to determine the potential for pollution of groundwater as well as to obtain the design of the sanitary landfill. The value of a soil survey is that in preliminary site selection, many areas can be found unfavorable without necessitating a detailed investigation.

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* Understood to be the usual practice of the U.S. Soil Conservation Service. U.S. Geological Survey profiles begin at slightly less than 10 feet and go to various depths depending on the particular circumstances.

a. Base Materials

As stated earlier two different types of soils are necessary for a sanitary landfill. The material of the bottom or base layer beneath the fill should be such as to hydrologically confine any leachate produced. Confinement necessitates the use of liners such as polyethylene sheeting, grouting with an impervious material or compacted clay liners at the base and sides of the landfill and an impermeable cover (9). These methods are costly and often impractical due to the size of a landfill. Use of a compacted clay liner appears to be the best method. This type of liner will allow any leachate which forms to uniformly migrate from the fill at a known rate favorable for natural renovation and dilution. Difficulties arise in trying to use a polyethylene liner in that the liner may break and leak during fill compaction. In the case of a grout curtain, gaps due to cracking during compaction also occur. The leakage problem is aggravated by the centralization of leachate seepage through the cracks when using the polyethylene liner or the grout curtain.

The use of clay, which has a low permeability when moist, can be effective in preventing pollutional problems with respect to the groundwater. Although the placement of a clay barrier may increase operational cost, this

preventive measure is justifiable for two reasons. Groundwater once polluted generally takes a long time to return to a usable quality because of its slow rate of movement. In aquifers of high yield, velocities of five to 60 feet a day are associated with hydraulic gradients of 10 to 20 feet per mile (12). Underflow through gravel deposits may travel several hundred feet per day while in more impervious materials such as clay, flows may be as low as a few feet per year. The second reason is the realization that the size and character of landfills are such that it would not be practical to remove the refuse if a water pollution problem should develop.

If clay material is unavailable or cannot be economically obtained, an alternative would be to select a disposal site where the natural movement of leachate will be shallow and toward a surface body of water or toward treatment facilities. Movement of leachate toward surface water instead of groundwater is feasible, perhaps desirable, because of the much higher assimilation capacity of surface water.

Geologic investigations include the kind of stratifications, rock formations, and the like that can conduct leachate to water sources such as aquifers, wells and water courses. The presence of hard, nonrippable* bedrock,

* not easily torn apart or broken up

sandy or gravelly slate within or immediately underlying the proposed trench bottom is undesirable from the standpoints of excavation and potential groundwater pollution.

The most favorable type of bedrock is shale, while sandstone, fissured limestone or dolomite are unfavorable. Even limestone or dolomite which is not known to be fissured is questionable.

b. Cover Materials

Another type of soil is needed for cover material. A soil is needed which will compact well to prevent water infiltration but which will allow gases produced by the decaying refuse to escape to the atmosphere. Buildup of carbon dioxide, methane and other gases not only can cause odor problems but create the possibility of fire and explosion hazards within the landfill (13). The presence of free carbon dioxide may cause acidity in ground water (4). This increases the aggressiveness of the water, thereby accelerating the corrosion of iron and steel and increasing the solvent action on calcium carbonate in concrete.

Clay having a low permeability when moist, is effective in keeping water from entering the fill but will not allow gas generated by the refuse to escape through the cover material. Clay is not desirable also because of its poor workability.

Two types of soils other than clay can be ruled out as possible cover materials. Peat and high organic soils cannot be used because they are most difficult to compact. In general, the best types of soils for cover materials are sandy loams, loam, silt loam, and sandy clay loam (11). See Table 1 for soil descriptions. Sandy loam is considered to be excellent since it contains about 60 percent sand and the remainder is clay and silt in approximately equal amounts with good workability and compaction qualities.

Consideration of final use of the land after completion of the landfill must be made in determining the best type of cover material to use. In general the soil selected for cover material should be favorable for growing plants. In most soils the A horizons have the best workability and the highest content of organic matter as compared to lower horizons in the soil. Therefore, it is desirable in the landfill operation to stockpile the topsoil* for final use in blanketing the top of the landfill. Since at least two feet -- and if trees are to be planted, three feet -- of soil cover is needed, the quantity of material required is large and effort should be made to select landfill sites which have close-at-hand adequate quality and quantity of cover material.

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* A horizon material

TABLE 1

SOIL CLASSIFICATION AND DESCRIPTION*

Textural Class	Composition, in percent Sand	Silt-size	Clay-size	
Sand	80-100	0-20	0-20	Distribution of particle sizes and relative predominance of fine or coarse grains give the soil its "feel", called texture.
Sandy loam	50-80	0-50	0-20	Sandy soil is loose and granular. Wet or dry, if squeezed and then released, it will crumble. Sandy loam has enough silt and clay material to make it somewhat coherent.
Loam	30-50	30-50	0-20	Loam consists of a relatively even mixture of sand and silt particles together with a smaller amount of clay. It is slightly plastic; that is, even when dry if it is squeezed it will form a cast that will withstand careful handling
Silt loam	0-50	50-100	0-20	Silt loam may be cloddy when dry, but these clods are easily crumbled. When wet the soil runs together.
Sandy clay loam	50-80	0-30	20-30	
Clay loam	20-50	20-50	20-30	A fine textured soil which breaks into hard clods when dry. The moist soil is plastic and will form a cast which will withstand much handling. When kneaded it will work into a heavy, compact mass.
Silty clay loam	0-30	50-80	20-30	
Sandy clay	55-70	0-15	30-45	
Silty clay	0-15	55-70	30-45	
Clay	0-55	0-55	30-100	

*Adapted from Soil Engineering by M. G. Spangler.

Sand-size particles - - 2 to 0.05 mm.
Silt-size particles ---0.05 to 0.005 mm.
Clay-size particles -less than 0.005 mm.

The U.S. Soil Conservation Service provides a Soil Survey Manual and various guide sheets for the use of its Conservationists and Soil Scientists. Tables 2 and 3, reproduced from the SCS guidelines, through the courtesy of Mr. Jack D. Crout, Area Soil Scientist, Southeast Texas Area, Rosenberg, Texas, show the ratings which that agency has placed on soils for sanitary landfill use.

B. Social/Political Considerations

For many years refuse disposal was not considered to be a problem. The refuse was hauled to a designated area and dumped. Often attempts were made to burn some of the refuse. Rats, flies, mosquitoes, and birds were numerous around these sites. As the country became more urbanized, many people became aware that open dumps were not only unsanitary, but were also a very inefficient way to dispose of refuse. Therefore, the theories of compaction to reduce the volume of refuse and burial to hide the refuse became relevant. This mode of disposal and its name tag "sanitary landfill" became a status symbol for cities and communities, one which was often misused.

The increasing public concern with the environment made it important for cities to dispose of their solid wastes at a site termed "sanitary landfill". In many instances this was only a public relations type of landfill -- little different from the open dump which preceded it. For this reason, many people today associate older impressions of open burning dumps with properly operated sanitary landfills. A result of this is the public opposition a

TABLE 2

SOIL LIMITATION RATINGS FOR TRENCH-TYPE SANITARY LANDFILLS (1)

Item affecting use		Degree of soil limitation		
		Slight (2)	Moderate(2)	Severe
Depth to seasonal high water table		Not class determining if more than 72 in.		Less than 72 in.
Soil drainage class		Excessively drained, somewhat excessively drained, well drained, and some(3) moderately well drained	Somewhat poorly drained and some (3) moderately well drained	Poorly drained and very poorly drained
Flooding		None	Rare	Occasional or frequent
Permeability(4)		Less than 2.0 in./hr.	Less than 2.0 in./hr	More than 2.0 in./hr.
Slope		0-15 pct.	15-25 pct.	More than 25 pct.
Soil texture(5) (dominant to a depth of 60 in.)		Sandy loam, loam, silt loam, sandy clay loam	Silty clay loam(6) clay loam, sandy clay, loamy sand	Silty clay, clay, muck, peat, gravel, sand
Depth to bedrock	Hard	More than 72 in.	More than 72 in.	Less than 72 in.
	Rippable	More than 60 in.	Less than 60 in.	Less than 60 in.

(1) Based on soil depth (5-6 feet) commonly investigated in making soil surveys.

(2) If probability is high that the soil material to a depth of 10-15 feet will not alter a rating of slight or moderate, indicate this by an appropriate footnote, such as "Probably slight to a depth of 12 feet," or "Probably moderate to a depth of 12 feet."

(3) Soil drainage classes do not correlate exactly with depth to seasonal water table. The overlap of moderately well drained soils into two limitation classes allows some of the wetter moderately well drained soils to be given a limitation rating of moderate.

(4) Reflects ability of soil to retard movement of leachate from the landfills; may not reflect a limitation in arid and semiarid areas.

(5) Reflects ease of digging and moving (workability) and trafficability in the immediate area of the trench where where may not be surfaced roads.

(6) Soils high in expansive clays may need to be given a limitation rating of severe.

Abbreviated from U.S. Soil Conservation Service Guide Sheet No. 7.

TABLE 3

SOIL LIMITATION RATINGS FOR AREA-TYPE SANITARY LANDFILLS

Item affecting use	Degree of soil limitation		
	Slight	Moderate	Severe
Depth to seasonal(1) water table	More than 60 in.	40-60 in.	Less than 60 in.
Soil drainage (1) class	Excessively drained, somewhat excessively drained, well drained, and moderately well drained	Somewhat poorly drained	Poorly drained and very poorly drained
Flooding	None	Rare	Occasional or frequent
Permeability(2)	Not class determining if less than 2 in./hr.		More than 2 in./hr.
Slope	0-8 pct.	8-15 pct.	More than 15 pct.

(1) Reflects influence of wetness on operation of equipment.

(2) Reflects ability of the soil to retard movement of leachate from landfills; may not reflect a limitation in arid and semiarid areas.

Abbreviated from U.S. Soil Conservation Service Guide Sheet No. 8

planner of a landfill meets unless acceptable operation of a landfill is familiar to the people of that particular area. Then the public generally accepts the landfill concept but on the terms that the location of the landfill will not be near where they live.

The increasing public concern with the environment is known to everyone. However, the lack of public concern is a problem which handicaps responsible officials in securing the necessary funds to operate and maintain adequate refuse collection and disposal systems. These may appear to be contradictory statements, but in reality the public's concern with the environment diminishes greatly whenever the cost to each individual is associated with this concern. To be sure, the recent popular clamor to clean up the environment has helped, but still the average citizen's interest is limited to having his refuse collected regularly and at minimal cost.

In the preliminary planning an active public information program should be included to explain to the public what comprises a sanitary landfill operation and what benefits and safeguards can be expected. A very good public relations tool which can be used in gaining public support is an architectural rendering or model of the completed landfill, which may illustrate a park, playground, golf course or other recreational facility that will become available on the site after the months or years of landfilling are completed. Other final uses may be parking and storage areas or botanical gardens. Because of ground surface settling and gas evolution problems, construction

of buildings on completed landfills generally speaking has been avoided. In some instances one-story rambling type buildings and airport runways for light aircraft have been constructed directly on sanitary landfills. Two and three story residential construction (motel type) where the ground level was left open and used for parking has been successfully demonstrated. Research has been done recently on the use of long piles driven into the ground beneath the level of the sanitary landfill bottom to be used for foundation stability in multi-story structures (14).

Social factors often determine whether or not a possible site is used as a landfill. Various agencies and individuals have reported the importance of properly informing the general public so that acceptance of landfills is possible. On July 26, 1972, the Houston Chronicle carried an article which is an excellent example of public opinion (15). Table 4 is a reprint of the article.

The article points out many of the factors which have been discussed in this report. Property depreciation, water supply pollution, the inadequacy of barriers, and the undesirability to nearby residences are all mentioned. This article points out the public's fear that air pollution in the form of odors; water pollution in the form of nutrient additions such as Nitrogen, Phosphorus, and Potassium, and ion addition such as cation and anion hardness; and land pollution in the form of unusable properties and land depreciation -- can and do cause serious complications in site selection.

TABLE 4

SANITARY LANDFILL APPLICATION BRINGS COMPLAINTS AT HEARING

BY KAY MOORE
Chronicle Staff

A group of east Harris County residents has complained again about another attempt by Waste Products, Inc., to install a sanitary landfill near Crosby.

About 70 residents appeared at a public hearing Tuesday to reiterate charges that the 200-acre landfill would pollute area water and devalue Crosby property.

The proposed permit would permit private garbage trucks to dump solid wastes into a pit on the site, at Crosby-Cedar Bayou Rd., eight miles north of Baytown.

The waste pit would be covered with dirt, leveled and possibly used as the site for a park when the landfill is full.

Waste Products, Inc., applied for a permit last April, but Dr. Walter A. Quebedeaux, county pollution control director, complained that the application did not prohibit the disposal of industrial wastes on the property.

A new application was filed in May. It specifies disposal of municipal wastes only.

Albert J. Shmidt, a retired chemist and Crosby school trustee, complained Tuesday that wastes from the landfill would contaminate the local water supply.

Shmidt said he has drilled several wells in the area and always reaches the water table at between 12 and 14 feet. The proposed landfill would be 14 feet deep.

L.G. Barnes, a geologist at DuPont Co., said Waste Product's plan to line the pit with clay is "risky" and probably would not prevent some seepage.

Edna Mae Dunaway, a realtor, said prospective customers are refusing to buy property in the area until the landfill issue is settled.

Dr. Max Smith, a laboratory consultant researching the proposed site, said it is separated from other property by trees, Cedar Bayou and an abandoned irrigation canal and would not be undesirable to nearby residences.

Representatives from the state health department, the Harris County Engineer's office and the City of Baytown supported the proposed landfill.

However, attorney L.A. Greene, Jr., representing the Crosby residents, said governmental agencies have not adequately studied the landfills.

He noted that Quebedeaux has objected to the present application unless Waste Products promises to remove immediately any materials dumped other than municipal wastes.

Hearing examiner Deral Castle of the county health department has taken the application under advisement and he will make a recommendation to Commissioners Court.

Final decision lies with the Texas Water Quality Board.

Article from: Houston Chronicle
July 26, 1972

A particularly bad aspect of this type of complication as compared to satisfying physical, economic, and regulatory criteria, is that this complication normally occurs after the other considerations have been approved. Often, when such a site is not permitted to be used because of the belated social considerations, additional cost is incurred in selection of another site. Therefore, it is advocated that a thorough investigation of land use characteristics in the areas near a potential site be made as part of the preliminary site selection procedure. This type of investigation will yield not only possible social implications, but also will contribute information to the economic evaluation. In the past, land use characteristics have been used in site selection, but the information gained from this type study has been used mainly for final use determination.

C. Economic Factors

Several considerations should be made in the economic evaluation of a site.

1. Haul Distance

The most important economic factor is usually haul distance. The economic distance to a site will vary from locality to locality depending upon capacity of collection vehicles, hauling time, and size and methods used by the collection company. The larger the quantity of refuse hauled per trip and the shorter the hauling time due to expressways, the greater the

distance the solid wastes can be hauled for the same cost. If a site is remotely situated, the cost of hauling may be high and the total cost unreasonable. It has been established that the normal maximum economical hauling distance to a refuse disposal site is 10 to 15 miles (16). Actually, hauling time is more important than hauling distance. Haul time is the time required to travel from the load center of the waste generation to the landfill site. The closer the site to the load center, the more economical its location. As a "rule of thumb", transfer stations should be considered for hauling distances greater than 20 miles. If a transfer station is used, hauling distances from 30 to 40 miles are acceptable. Also, planners should avoid choosing sites which will require the large transfer vehicles to traverse through residential streets.

The selected site should have several access roads so that if one route is temporarily unusable the site can still be used. The routing of collection vehicles to the site should also be considered to determine the effects of this traffic on the design tonnage of the roads and bridges, as well as the clearance distances of the underpasses (17).

2. Accessibility

Another consideration which is related to hauling distance is accessibility. Although this is not normally considered to be an economic factor, accessibility is important where roads

have to be constructed or maintained. Since traffic should be able to reach the site five or six days per week, it is important to have good access roads and, if possible, alternate routes. Alternate routes can prevent costly traffic tie-ups for the collection vehicles when road or bridge maintenance must be performed. If possible, it is best to locate sites near major highways in order to facilitate the use of existing arterial roads.

3. Cost of land

Many sanitary landfill planners do not consider the cost of land in an economic analysis because its value will either remain the same or appreciate in future years. However, the writers believe that inasmuch as the initial capital outlay will place constraints on the selection process, it should be considered. For example, in Kansas City, Kansas, land was purchased for approximately $12,000 per acre while in Frostburg, Maryland, land formerly used for strip mining was leased for $50/acre for a sanitary landfill (6).

4. Pre-development for Landfill Use

Another economic factor to be considered is the amount of development required before operation of the landfill can commence. Pre-development costs will vary depending upon the physical characteristics of the site. Land use characteristics

in the surrounding locale are important parameters in estimating initial and developmental cost of a site. Grazing and pasture lands are probably the least costly to buy and develop. Cultivated lands would usually rank second in terms of lowest expenditures, followed by woodland and then urban areas.

5. Availability of Cover Material

The availability of cover material is another economic factor to consider. A landfill location that has cover material on-site or nearby should be more economical than one where cover material must be hauled in from a distance. A rough estimate of the need for cover material, using six inches of cover material between lifts* and a final cover of two feet compacted over the fill when it is completed is one cubic yard per capita per year (16).

6. Future Use

In general, there are two schools of thought for the future use of sanitary landfill locations after the fills have been completed: (1) use the site as open space, and (2) use it for the construction of facilities. The Solid Waste Management Office, EPA, recommends that completed fills be used solely for open space such as a green area, a recreational

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* layer of solid waste

area, an agricultural area, or in some cases, in conjunction with open space for the construction of light buildings (6). Other authorities believe that completed landfills can be utilized as sites for high-rise buildings, recognizing that settlement and gas evolution will require special designs and more expensive construction techniques. The final development cost of the site following the landfilling is certainly an economic factor that deserves careful attention.

D. Regulatory Aspects

There are certain procedures which must be followed in the establishing of a sanitary landfill site according to regulatory criteria. For the State of Texas the State Department of Health has been established as the state solid waste agency with respect to the collection, handling, storage, and disposal of municipal solid waste by Senate Bill 125, Sixty-First Legislature, Regular Session, 1969 (18). The Texas Water Quality Board is designated as the state solid waste agency with respect to industrial solid waste. The following excerpts were selected to familiarize the reader with the authoritative structure outlined by the Bill:

A-5.4 County Governments -- The Texas State Department of Health encourages the county governments to exercise the authority provided in Article 4477-7, V.T.C.S., regarding the management of solid waste. Counties are expected at least to administer and enforce the provisions

of these rules, standards, and regulations and it is recommended that each county develop rules and regulations specific to its peculiar needs which shall exceed the requirements contained herein. The provisions of Article 4477-7, V.T.C.S., allow county governments to require and issue licenses authorizing and governing the operation and maintenance of sites used for the disposal of solid waste not in the territorial limits of a municipality. The law requires that no license for disposal of solid waste may be issued, renewed, or extended without the prior approval, as appropriate, of the Department or the Board. Under sub-Section 8 (g), the Department and the Board are considered as necessary and indispensable parties to any suit filed by a local government for the violation of any provision of the Act.

A-6. Relationship with County Permit System

The "Solid Waste Disposal Act", Article 4477-7, V.T.C.S., empowers counties to require and issue licenses authorizing and governing the operation and maintenance of sites used for the disposal of solid waste not within the territorial limits of incorporated cities and towns. The county shall mail a copy of the license application or a summary of its contents to the Department, the Board, and to the mayor and health authorities of any

city within whose extraterritorial jurisdiction the solid waste disposal site is located. The governmental entities to whom the information is mailed shall have a reasonable time, as prescribed by the county, to submit comments and recommendations on the license application before the county acts on the application.

B-2. Approval of Municipal Solid Waste Handling and Disposal Activity

No new solid waste handling and disposal facilities shall be operated without approval by local authorities and the Department prior to being placed into operation. In the absence of local response, the Department may exercise final authority. Separate approval shall be considered for each site.

These sections of Senate Bill 125 show that authority to issue permits which allow for the location and operation of a sanitary landfill is held either by a county-state combination or by a city-state combination. In either case the final authority is at the state level. The permit system was set up to insure a type of control over the location and operation of landfills. The article reprinted from the Houston Chronicle, Table 4, illustrates the usefulness of this type of control. It allows the general public a voice and consideration in the selection of sites.

At the present time most regulatory landfill criteria are based upon rather rigid and arbitrary standards. These criteria have proven adequate for dust repressions, insect control and site aesthetics. However, leachate generation, and surface and ground water pollution are not incorporated. Each landfill is different in geographical location, climate, geological formation and other parameters. To achieve a landfill that will not cause any deleterious effect on the environment it is necessary for each site to be developed to take advantage of its particular site characteristics, as discussed in the preceding sections of this report. It is hoped that in the future designs for landfills will be based on consideration of all of these characteristics and on desired performance criteria rather than on rigid and arbitrary standards.

IV. CLOSURE

In the next report, the second of this series, the regulatory features of the State of Texas pertaining to site selection will be outlined in detail. Therefore no further attempt regarding regulatory considerations will be made here. In summation, a permit to locate and operate a landfill for municipal solid wastes is necessary and this permit can be obtained from a city, county or state health agency according to the site location. If industrial wastes are to be disposed of, the Texas Water Quality Board will issue the permit.

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